SECTION 1
INTRODUCTION

BACKGROUND

Increased demand for spectrum for mobile services has focused attention within the national and international radiocommunications community on the frequency bands between 1 and 3 GHz. Most of the new technologies will facilitate implementation of radio uses in the terrestrial personal mobile environment, including business, and residential areas. Some will involve satellite technology, and manufacturers have considered this frequency range for both uplinks and downlinks. Aside from the identification and allocation of spectrum exclusively for these uses, sharing with existing activities could provide needed spectrum. In order to share spectrum with other radio frequency (RF) uses, the emission characteristics of those other uses must be known.

Some service providers and manufacturers have considered development of new systems near or in the 2400-2500 MHz band. The International Telecommunication Union (ITU) designates 2450 MHz ± 50 MHz for use by industrial, scientific, and medical (ISM) equipment.[1/] Among the ISM devices operating at that frequency are domestic microwave ovens. The presence of approximately 80 million ovens within the United States and 200 million worldwide operating nominally at 2450 MHz, and the investment in terms of industry costs and public outlays, make microwave ovens a major factor in considering options for the future radio use of 2400-2500 MHz and surrounding bands.[2/] Some radio services may operate in an environment where emissions from individual ovens are the primary concern. For other radio services, aggregate microwave oven sources may have a greater impact. Therefore, emission characteristics from individual microwave ovens and aggregate microwave oven sources must be determined. The potential economic impact of these radio-based technologies makes resolution of issues related to compatibility with microwave ovens essential.

National and international radio regulations specify that radio operations in the ISM bands must accept harmful interference that may result from ISM applications. Also, in order to promote ISM use of ISM designated bands, no U.S. or international ISM emission limits have been applied within the ISM bands, and specifically between 2400 and 2500 MHz.

1/ *ITU Radio Regulations* #752, International Telecommunication Union, Geneva Switzerland, 1990, p. RR8-105.

2/ Other ISM devices include, for example, industrial and commercial grade ovens or heaters for curing and drying of commodities, medical diathermy equipment, and plasma generators. Though many of these systems operate at higher power levels than domestic microwave ovens, their fewer numbers may lower their impact on use of radio systems near the 2400-2500 MHz band. Therefore, ensuring compatible radio operations with these ISM uses requires a separate set of considerations. The presence of these systems should be reflected in measurements of aggregate signal levels. NTIA will perform aggregate measurements as part of a subsequent task.

Thus, design of radio equipment to operate in the 2400-2500 MHz band presents a significant challenge.

Outside the ISM bands, ISM emission limits have been established by the Federal Communications Commission (FCC), and adopted by the National Telecommunications and Information Administration (NTIA), to enhance compatibility between microwave ovens and radio services.[3/] National and international regulations stipulate that ISM equipment must not cause interference outside the ISM band. However, in the case of domestic microwave ovens, enforcement of this regulation could be both difficult and expensive because of the large number of ovens in the hands of the public. Furthermore, if interference to a radio service occurs, it may be caused by an aggregate of microwave oven sources, not a single oven. Since enforcement of this regulation may be impractical, radiocommunications system developers designing equipment for near term implementation must design their equipment to be compatible with the current RF emission environment. Implementation of new services and technologies in the long term provides more flexibility since there may be time to update emission standards for microwave ovens. If applicable emission limits are to continue to facilitate compatibility, spectrum management authorities must periodically review and revise them, based on the characteristics of those future radio requirements.

The International Special Committee on Radio Interference (CISPR) Subcommittee B is currently developing international limits for ISM emissions above 1 GHz.[4/] Subcommittee discussions have focused on the emission levels of domestic microwave ovens. The levels emitted by ovens currently in use, the manufacturers' ability to limit emissions outside the ISM band (with associated costs), and the needs of radio users constitute the primary factors considered in negotiating the limits. The outcome of CISPR discussions will impact U.S. oven manufacturers by potentially establishing the most widely used standard for microwave ovens sold outside the United States. If the FCC chooses to have its standards conform with CISPR, these discussions will impact equipment designed for U.S. markets also. The lifespan of microwave ovens necessitates that agreement be reached on these issues relatively soon. Standards implemented today, and microwave ovens built to those standards, will affect the radio environment of systems to be placed in operation ten or more years in the future.

In 1991, NTIA determined that, for the Broadcast Satellite Service (Sound) to be accommodated between 2300 and 2400 MHz, microwave oven emissions must be taken into account in system design through sophisticated signal processing techniques, such as time

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3/ Emission standards and measurement approaches pertaining to radio interference and electromagnetic compatibility are distinct from those dealing with radiation hazards to people. Within this effort, NTIA did not measure emissions in a manner applicable to evaluate bioeffects. Radiation hazard aspects are regulated by the Food and Drug Administration under *Title 21, Code of Federal Regulations*, Section 1030.10, "Performance Standards for Microwave and Radio Frequency Emitting Products".

4/ CISPR is an body of the International Electrotechnical Committee (IEC) and develops industry standards for preventing radio interference. The American National Standards Institute (ANSI) provides U.S. representation.

and frequency interleaving and forward error correction.[5/] Measurements performed by the Institute for Telecommunication Sciences (ITS) showed that the ovens emit RF energy across a wide spectrum, with high peak levels outside the frequency band designated for ISM use.

The results of the previous NTIA study and the requirement to ensure that U.S. manufacturers and radio users are adequately considered in the CISPR deliberations necessitated additional testing and analysis to more accurately determine the level of emissions from individual ovens, the level of aggregate emissions in large metropolitan areas, and the level of emissions outside the 2400-2500 MHz band acceptable to authorized radio services. On this basis, NTIA began a three-part effort to

1. measure the emissions from a number of new microwave ovens, checking the impact of measurement procedures on the results, and reviewing the utility of measurement procedures in assessing compatibility of oven emissions,

2. measure the aggregate levels of emissions in the 2300-2600 MHz band near large metropolitan areas,

3. determine the level of emissions acceptable to a variety of receiver technologies, formulate appropriate emission limits and methods of measurement, and identify services that can compatibly operate in the 2400-2500 MHz ISM band and adjacent bands.

This report represents the results of the first of those three tasks. The measurement results described here provide useful information for evaluating the potential impact of microwave ovens on radio systems. However, the results must be considered as a whole. For example, the pulsed nature of oven emissions make peak measurements useful. Nevertheless, the use of a peak envelope measured over a period of time without recognizing the pulse duty cycle and frequency shifts characteristic of microwave ovens will lead to erroneous interference predictions. Furthermore, the aggregate measurements planned as the second task will be helpful for determining the impact of large numbers of microwave ovens on systems, such as spaceborne receivers, which are more susceptible to aggregate microwave oven emissions. Taken as a whole, the spectral emission characteristics, time waveforms, and statistical summaries provide a more complete and valuable picture. No attempt has been made by NTIA, within this first task, to specifically analyze the potential impact of the oven emissions.

OBJECTIVES

The objectives of these microwave oven measurements are to

5/ Filippi, C.A., R.L. Hinkle, K.B. Nebbia, B.J. Ramsey, and F.H. Sanders, NTIA Technical Memorandum 92-154, *Accommodation of Broadcast Satellite (Sound) and Mobile Satellite Services in the Band 2300-2450 MHz*, Department of Commerce, National Telecommunications and Information Administration, January 1992, p. 2-3.

1. identify and evaluate the measurement procedures specified by the FCC and by CISPR and investigate alternate measurement techniques,

2. characterize microwave oven emissions in the 2400-2500 MHz ISM band and adjacent bands (2300-2400 MHz and 2500-2600 MHz) on a frequency and time basis,

3. characterize microwave oven harmonic emissions up to the 7th harmonic,

4. identify microwave oven designs that minimize emissions outside the ISM band.

APPROACH

The following approach was taken to meet the objectives of this task.

1. Fourteen microwave ovens were identified for testing, twelve supplied directly by manufacturers and two purchased by ITS. One of the manufacturer-supplied ovens was not tested due to its use of an unusual electrical connector.

2. Preliminary measurements were performed to

   a) determine the difference in test results using the FCC, CISPR, and an NTIA/ITS-specified test procedure,

   b) identify the impact of test parameter variations on test results in order to determine the best parameters to use during further testing,

   c) determine the 2300-2600 MHz spectral emission characteristics of the ovens in order to identify ovens for detailed tests.

3. Detailed measurements were performed on selected ovens to

   a) determine oven spectral emission characteristics from 2300-2600 MHz using predetermined receiver bandwidths and test parameters,

   b) characterize oven time waveform characteristics at a number of specific frequencies,

   c) determine oven emission characteristics in harmonic bands up to the 7th harmonic using predetermined receiver bandwidths and test parameters.

4. Based on measured data, amplitude probability distributions and frequency stability were determined.